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TITLE: HIGH STRENGTH STEEL WIRE FOR SPRING

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ABSTRACT:

PROBLEM TO BE SOLVED: To provide steel wire for a spring which has excellent coiling properties even in high strength satisfying tensile strength of ≥1,900 MPa.

SOLUTION: The heat treated steel wire for a spring has a composition containing, by mass, 0.4 to 1.0% C, 0.9 to 3.0% Si, 0.1 to 2.0% Mn, ≤2.5% Cr, 0.001 to 0.007% N, ≤0.015% P and ≤0.015% S, and the balance iron with inevitable impurities, and has tensile strength TS of ≥1,900 MPa. As for cementitic spheroidal carbides occupied in the microscopic cross section, the space factor of those with a diameter of the equivalent circle of ≥0.2 μm satisfies ≤7%, the density of those with a diameter of the equivalent circle of 0.2 to 3 μm satisfies ≤1 piece/μm2, the density of those with a diameter of the equivalent circuit of >3 μm satisfies ≤0.001 pieces/μm2, also, the old austenitic grain size number is ≥10, the maximum carbide size is ≤15 μm, and the maximum oxide size is ≤15 μm.

CLAIMS

[Claim(s)]
[Claim 1] By mass %, C:0.4 - 1.0%, Si:0.9-3.0%, Mn:0.1-2.0%, Cr: Less than [2.5%] (it contains 0%), P:0.015% or less, S:0.015% or less, Remainder iron and an unescapable impurity are included N:0.001 to 0.007%. Tensile strength TS is related with the cementite system spheroidal carbide occupied to 1900 or more MPas and a speculum side. The rate of occupancy area of 0.2 micrometers or more of projected area diameters 7% or less, 2 or less [per piece/micrometer] and a 3 micrometer **'s of projected area diameters existence consistency fill [the existence consistency of 0.2-3 micrometers of projected area diameters] two or less [0.001 //micrometer]. And heat treatment steel wire for springs with which the old austenite particle-size number is characterized by more than No. 10 and the diameter of the maximum carbide being [15 micrometers or less and the diameter of the maximum oxide] 15 micrometers or less.
[Claim 2] Heat treatment steel wire for springs according to claim 1 furthermore characterized by including one sort (W:0.05 - 1.0%, and Co:0.05-3.0%), or two sorts by mass %.
[Claim 3] Heat treatment steel wire for springs given in either of claims 1 or 2 furthermore characterized by including Mg:0.0002-0.01% by mass %.
[Claim 4] Heat treatment steel wire for springs according to claim 1 to 3 furthermore characterized by including one sort (Ti:0.005-0.1%, Mo:0.05-1.0%, V:0.05 - 0.7%, and Nb:0.01-0.05%), or two sorts or more by mass %.
[Claim 5] Heat treatment steel wire for springs according to claim 1 to 4 furthermore characterized by including B:0.0005 - 0.006% by mass %.
[Claim 6] Heat treatment steel wire for springs according to claim 1 to 5 furthermore characterized by including one sort (nickel:0.05-3.0% and Cu:0.05-0.5%) or two sorts by mass %.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] Coiling of this invention is carried out between the colds, and it relates to the spring steel wire which has high intensity and high toughness.
[0002]
[Description of the Prior Art] With lightweight-izing of an automobile, and high-performance-izing, a spring is also high-intensity-ized and the spring is presented with high-strength steel which exceeds tensile strength 1500MPa after heat treatment. Recent years also require the steel wire exceeding tensile strength 1900MPa. It is for securing the ingredient degree of hardness which is convenient as a spring, even if it softens a little with heating of straightening annealing at the time of spring manufacture, nitriding treatment, etc.
[0003] As the technique, by JP,57-32353,A, the detailed carbide which dissolves with hardening by adding elements, such as V, Nb, and Mo, and deposits by annealing is made to generate, and it restricts a motion of a rearrangement and it is supposed that a setting-proof property will be raised.
[0004] On the other hand, by the manufacture approach of the coiled spring of steel, coiling is heated and carried out to the austenite region of steel, and there is coiling between the colds which carries out coiling of coiling between heat which performs hardening annealing, and the high strength steel wire which gave hardening annealing to steel between the colds beforehand after that. In coiling between the colds, since the oil temper processing in which rapid heating forced cooling is possible, RF processing, etc. can be used at the time of manufacture of steel wire, it is possible to make small the old austenite particle size of spring material, and the spring which was excellent in the destructive property as a result can be manufactured. Moreover, since a facility of the heating furnace in a spring production line etc. can be simplified, there is an advantage, such as leading to reduction of facility cost also for a spring manufacturer, and, recently,-izing of a spring between the colds is advanced.
[0005] However, if the reinforcement of the coiling spring steel wire between the colds becomes large, it breaks at the time of coiling between the colds, and cannot fabricate in a spring configuration in many cases. Since reinforcement and workability were incompatible, coiling had to be carried out by the approach which can be referred to as industrially disadvantageous. Usually, in the case of a valve spring, coiling of hardening tempering processing on line and the so-called steel wire which carried out oil temper processing is carried out between the colds, but, for example by JP,05-179348,A, in order to prevent the breakage at the time of coiling, such as heating and carrying out coiling to 900-1050 degrees C, and carrying out tempering processing at 425-550 degrees C after that, a wire rod is heated at the time of coiling, coiling of the deformation is carried out at easy temperature, and in order to obtain high intensity after that, temper processing after coiling is performed. Since it becomes the cause of heat treatment dispersion of a spring dimension or processing efficiency falls extremely, heating at the time of such coiling and the temper processing after coiling are inferior compared with cost and the spring by which coiling between the colds was carried out in respect of precision.
[0006] Moreover, although invention which observed the mean particle diameter of the carbide of Nb

and V systems like JP,10-251804,A, concerning the particle size of carbide is made, it is shown that just control of the mean particle diameter of V and Nb system carbide is inadequate. In this advanced technology, with the cooling water under rolling, there is description which is anxious about abnormal structure being generated (paragraph 0015), and dry type rolling is recommended substantially. This is an unsteady activity industrially, and if an ununiformity will be produced in a circumference matrix organization even if differing from the usual rolling clearly is presumed and it controls a mean diameter, it will have suggested producing a rolling trouble.

[0007]

[Problem(s) to be Solved by the Invention] Coiling of this invention is carried out between the colds, and it is making to offer the spring steel wire of 1900 or more MPas of tensile strength compatible in sufficient atmospheric-air reinforcement and coiling workability into the technical problem.

[0008]

[Means for Solving the Problem] Artificers came to develop the carbide in steel which did not attract attention, especially the spring steel wire which reconciled high intensity and coiling nature with restricting the magnitude of a cementite by the conventional spring steel line.

[0009] That is, this invention makes a summary the steel materials shown below.

[0010] By mass %, (1) C:0.4 - 1.0%, Si:0.9-3.0%, Mn: 0.1-2.0%, less than [Cr:2.5%] (it contains 0%), P:0.015% or less, Remainder iron and an unescapable impurity are included S:0.015% or less and N:0.001 to 0.007%. Tensile strength TS is related with the cementite system spheroidal carbide occupied to 1900 or more MPas and a speculum side. The rate of occupancy area of 0.2 micrometers or more of projected area diameters 7% or less, 2 or less [per piece/micrometer] and a 3 micrometer **'s of projected area diameters existence consistency fill [the existence consistency of 0.2-3 micrometers of projected area diameters] two or less [0.001 //micrometer]. And heat treatment steel wire for springs with which the old austenite particle-size number is characterized by more than No. 10 and the diameter of the maximum carbide being [15 micrometers or less and the diameter of the maximum oxide] 15 micrometers or less.

[0011] (2) further -- mass -- % -- W -- : -- 0.05 - 1.0 -- % -- Co -- : -- 0.05 - 3.0 -- % -- one -- a sort -- or -- two -- a sort -- containing -- things -- the description -- ** -- carrying out -- the above -- (-- one --) -- a publication -- a spring -- ** -- heat treatment -- steel wire .

[0012] (3) Heat treatment steel wire for springs the above (1) furthermore characterized by including Mg:0.0002-0.01% by mass %, or given in either of (2).

[0013] (4) further -- mass -- % -- Ti -- : -- 0.005 - 0.1 -- % -- Mo -- : -- 0.05 - 1.0 -- % -- V -- : -- 0.05 - 0.7 -- % -- Nb -- : -- 0.01 - 0.05 -- % -- one -- a sort -- or -- two -- a sort -- more than -- containing -- things -- the description -- ** -- carrying out -- the above -- (-- one --) - (-- three --) -- either -- a publication -- a spring -- ** -- heat treatment -- steel wire .

[0014] (5) Heat treatment steel wire for springs given in either of above-mentioned (1) - (4) furthermore characterized by including B:0.0005 - 0.006% by mass %.

[0015] (6) further -- mass -- % -- nickel -- : -- 0.05 - 3.0 -- % -- Cu -- : -- 0.05 - 0.5 -- % -- one -- a sort -- or -- two -- a sort -- containing -- things -- the description -- ** -- carrying out -- the above -- (-- one --) - (-- five --) -- either -- a publication -- a spring -- ** -- heat treatment -- steel wire .

[0016]

[Embodiment of the Invention] Specifying a chemical entity, in order to obtain high intensity, he is controlling the carbide configuration in steel by heat treatment, and an artificer came to invent the steel wire which secured sufficient coiling property to manufacture a spring.

[0017] The detail is shown below. First, the reason for having specified the chemical entity of steel is explained.

[0018] C was an element which has big effect on the fundamental strength of steel materials, and in order to obtain sufficient reinforcement, it could be 0.4 - 1.0%. reinforcement sufficient at less than 0.4% is obtained -- not having -- other alloy elements -- further -- abundant -- not supplying -- it does not obtain, but since it becomes a hyper-eutectoid by ** 1.0% and a big and rough cementite is deposited so much, toughness is reduced remarkably. This reduces a coiling property to coincidence.

[0019] Si was an element required in order to secure the reinforcement, the degree of hardness, and setting-proof nature of a spring, and since required reinforcement and setting-proof nature ran short when few, it made 0.9% the minimum. Moreover, Si has the effectiveness which makes small the rate of grain boundary occupancy area of grain boundary precipitate by there being balling-up and effectiveness made detailed and adding the carbide system sludge of a grain boundary positively. However, if it adds too much so much, it not only stiffens an ingredient, but it will stiffen. Then, 3.0% was made into the upper limit in order to prevent the embrittlement after hardening annealing.
[0020] Mn makes 0.1% a minimum, in order to fully obtain a degree of hardness, and in order to fix as MnS S which exists in steel and to control a fall on the strength. Moreover, the upper limit was made into 2.0% in order to prevent embrittlement by Mn.
[0021] Although N stiffens the matrix in steel, when alloy elements, such as Ti and V, are added, it exists as a nitride, and affects the property of steel wire. In the steel which added Ti, Nb, and V, it is easy to become the deposit site of the carbide with which generation of carbon nitride becomes easy and serves as a pinning particle of the formation of austenite grain detailed, a nitride, and carbon nitride. Therefore, a pinning particle can be stably generated on various heat treatment conditions given by spring manufacture, and the austenite particle size of steel wire can be controlled minutely. 0.001% or more of N is made to add from such a purpose. On the other hand, superfluous N causes big and rough-ization of the carbon nitride and carbide which generated the nitride and the nitride as a nucleus. For example, if big and rough TiN is deposited or it adds B in adding Ti, BN will be deposited and a destructive property will be spoiled. Then, let 0.007% by which such evil is not accompanied be an upper limit.
[0022] Although P stiffens steel, it produces a segregation further and embrittles an ingredient. P segregated especially to the austenite grain boundary causes delayed fracture etc. by the fall of an impact resistance value, or invasion of hydrogen. Therefore, little direction is good. Then, it restricted to 0.015% or less from which an embrittlement inclination becomes remarkable.
[0023] Steel will be embrittled if S as well as P exists in steel. Although the effect is made small as much as possible by Mn, in order that MnS may also take the gestalt of inclusion, a destructive property falls. Since destruction is especially produced from MnS of a minute amount in that of high-strength steel, it is desirable to also lessen S as much as possible. 0.015% from which the bad influence becomes remarkable was made into the upper limit.
[0024] When there are many additions, the cementite seen after hardening annealing is made it not only to cause the increase of cost, but to make it big and rough, although it is an effective element in order that Cr may raise hardenability and resistance to temper softening. Breakage is made easy to produce at the time of coiling, in order that a wire rod may stiffen as a result. Then, 2.5% from which embrittlement becomes remarkable was made into the upper limit. About the addition of Cr, it is 0.7% or less preferably, and when especially C is 0.6% or more, the direction which controlled the amount of Cr(s) can control big and rough carbide generation, and tends to be compatible in reinforcement and coiling nature. On the other hand, in performing nitriding treatment, the direction where Cr is added can make the hardening layer by nitriding deep. Therefore, about 0.3 - 0.5% is desirable in this case.
[0025] W generates carbide in steel and has the work which raises reinforcement while it raises hardenability. Therefore, to add as much as possible is more desirable. The description of W is making the configuration of the carbide containing a cementite detailed unlike other elements. When effectiveness was not seen at less than 0.05% but the addition exceeded 1.0%, big and rough carbide was produced, and since there was a possibility of spoiling mechanical properties, such as ductility, on the contrary, the addition of W was made into 0.05 - 1.0%.
[0026] Although Co reduces hardenability, it can secure hot reinforcement. Moreover, in order to check generation of carbide, there is work which controls generation of the big and rough carbide which poses a problem by this invention. Therefore, big and rough-ization of the carbide containing a cementite can be controlled. Therefore, adding as much as possible is desirable. Since the effectiveness would be saturated with less than 0.05% if the effectiveness is small and exceeds 3.0% when adding, it could be 0.05 - 3.0%.

[0027] It is thought that W and Co have the work to which both control generation of a big and rough cementite although just the behavior in the inside of steel differs. That is, it is thought that Co controls the carbide generation itself, and W controls growth of a cementite and controls big and rough-ization.
[0028] Mg is an oxide generation element and generates an oxide in molten steel. The temperature region is higher than the generation temperature of MnS, and has already existed in the MnS generate time in molten steel. Therefore, it could use as a deposit nucleus of MnS and found out that distribution of MnS was controllable by this. That is, in order to distribute Mg system oxide in molten steel more minutely than Si and aluminum system oxide which are seen, MnS which used Mg system oxide as the nucleus will be minutely distributed in steel. Therefore, even if it is the same S content, MnS distribution changes with existence of Mg and the direction becomes more detailed [MnS particle size] adding them. MnS will be made detailed, if a minute amount is also obtained enough and the effectiveness is more than Mg0.0002%. However, since it is hard to remain in molten steel if it exceeds 0.01%, it is considered an upper limit 0.01% of industrially. Then, Mg addition was made into 0.0002 - 0.01%. According to effectiveness, such as MnS distribution, this Mg has effectiveness in the improvement in corrosion resistance and delayed fracture, rolling crack prevention, etc., and is added as much as possible, it is [direction] desirable and a desirable addition is 0.0005 - 0.01%.
[0029] Ti, Mo, V, and Nb deposit as a nitride, carbide, and carbon nitride in steel. Therefore, if one sort or two sorts or more are added for these elements, these sludges can be generated and resistance to temper softening can be obtained, and even if it passes through heat treatment of straightening annealing into which it is put at annealing in an elevated temperature, or a process, nitriding, etc., it cannot soften, but high intensity can be demonstrated. In order that this may control the fall of the interior degree of hardness of a spring after nitriding or may make hot setting and straightening annealing easy, it makes the fatigue property of a final spring improve.